

**ESTIMATION OF MULE DEER POPULATION SIZE, SURVIVAL, AND A DESCRIPTION OF
MOVEMENTS IN ROCKY MOUNTAIN NATIONAL PARK**



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Rocky Mountain National Park
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SUMMARY

Rocky Mountain National Park (ROMO) biologists and wildlife managers were concerned that mule deer (*Odocoileus hemionus*) populations were declining in the Estes Valley, which is winter range for ROMO deer. However, there were no data to document this purported decline in mule deer population sizes in the Estes Valley, only anecdotal field observations. To develop a deer management strategy, ROMO needed baseline information on their mule deer population. We marked deer with visible collars and conducted a mark-resight study in the winters of 2001, 2002, and 2003 to estimate annual wintering population size. We radiocollared and located deer from June 2001 to June 2003 to estimate survival rates and describe movements of mule deer. Using field data, we parameterized a population model to explore dynamics of the Estes Valley mule deer population and help ROMO biologists to optimally plan future data collection efforts.

From December 2001 to December 2003, mule deer population size decreased from 833 (95%CI = 659–1048) to 561 (95%CI = 498–632). Survival rates were similar for male and female deer, averaging 0.77 (95%CI = 0.69–0.85) during the study period. There was a mix of migratory and sedentary deer in the Estes Valley population. Approximately 49% (95%CI = 33–65%) of Estes Valley mule deer migrated from winter to summer range, with a mean migration distance of 20.2 km (95%CI = 16.3–24.1 km). Most migration movements were west or northwest, and 15–20% of the radiocollared deer moved close to or over Continental Divide during the summers of 2002 and 2003. Additionally, from an independent ongoing deer movement study (Conner and Miller 2004), we found some interchange during the summer between deer from Estes Valley and deer wintering in other areas: about 5–10% of 24 deer radiocollared on winter range in the Masonville area summered in the Estes Valley. There was also limited interchange with deer wintering along the Poudre River and in the Lyons area.

Based on 1996–2003 chronic wasting disease (CWD) surveillance samples collected by Colorado Division of Wildlife (CDOW), CWD prevalence in the Estes Valley was 5.4% ($n = 261$, 95%CI = 2.7–8.1%). Because CWD exists at higher prevalences in the Lyons and Masonville areas (10.4% and

18.3% respectively; Conner and Miller 2004) than in the Estes Valley, it is unlikely that CWD will flow from the Estes Valley to the foothills. However, given the western migration of some Estes Valley deer over the Continental Divide, it is possible that CWD could flow from the Estes Valley into the Middle Park area, where prevalence is relatively low (0.8% and 2.0% for mule deer and elk respectively; CDOW unpublished data). CWD monitoring should be continued on the western slope of ROMO to monitor potential spread of CWD into Middle Park.

Predicted population sizes from the population model were not in accordance with mark-resight estimates unless harvest was included in the model. However, there was no way to balance harvest to match the population decline seen 2001–2003 and then have a sustainable mule deer population. This may stem from the fact that the model was very sensitive to the number of does harvested from the Estes Valley. Because observed adult survival is relatively low for mule deer, doe harvest appears to have considerable influence on Estes Valley mule deer population dynamics. If ROMO decides a management goal is to maintain Estes Valley mule deer population size close to the current level, then doe harvest should be minimized. However, the goal of maintaining the mule deer at current densities may conflict with goals to manage the CWD. With these potentially conflicting goals, we recommend that, at a minimum, doe harvest is tracked for the Estes Valley mule deer population.

For future research, we suggest a robust design capture-recapture methodology as an efficacious and cost-effective strategy for future monitoring of the Estes Valley mule deer population.

INTRODUCTION

Rocky Mountain National Park (ROMO) biologists and wildlife managers were concerned that mule deer (*Odocoileus hemionus*) populations were declining in the Estes Valley, which is winter range for deer that reside at least seasonally in the park. On the eastern slope of ROMO, park managers estimated that mule deer population size declined from approximately 650 to 175 over the past 60 years. Concerns of park biologists reflect a broader concern about mule deer decline throughout the intermountain west (Unsworth et al. 1999, Ballard et al. 2001), with special concerns about declines in the mid-1990s (Unsworth et al. 1999, Pac 2001). Alleged causes for the decline include loss of habitat, predation, elk competition, white-tailed deer competition, over harvest, shifts in forestry practices, or some combination of all (Carpenter 1998). In addition, chronic wasting disease (CWD) exists in the Estes Valley mule deer (Spraker et al. 1997, Miller et al. 2000, Wolfe et al. 2002, Conner and Miller 2004); CWD may also contribute to mule deer declines (Gross and Miller 2001). However, there were no data documenting the purported decline in mule deer population sizes in Estes Valley, only anecdotal observations. To develop a deer management strategy, ROMO needed baseline information on their mule deer population.

To provide ROMO biologists and managers with baseline information, our primary objectives were to (1) estimate population size, (2) estimate survival probabilities, and (3) describe movements of mule deer in ROMO and the Estes Valley. Our secondary objectives were to build a mule deer population model, which would help ROMO biologists to optimally plan future data collection efforts to effectively monitor the mule deer population.

We note that this study was undertaken as part of a joint effort with the Colorado Division of Wildlife (CDOW) and Colorado State University (CSU). The main objectives of CDOW were to determine whether mule deer movements from areas of high chronic wasting disease (CWD) prevalence were related to levels of prevalence in surrounding areas and/or mule deer populations (Conner and Miller 2004) and to evaluate an antemortem diagnosis for CWD in free-ranging mule deer and to compare antemortem to postmortem prevalence estimates (Wolfe et al. 2002); the main objective of CSU was to

study the effects of land use on CWD prevalence in several urban/exurban interface areas, including Estes Park (Farnsworth et al. 2004). Thus, research done for ROMO as part of this study was leveraged against CDOW and CSU field efforts already underway.

METHODS

Capturing, Collaring, and Monitoring

Deer were captured by chemical immobilization, primarily during December–March (Wolfe et al. 2002). Deer were marked with individually identifiable neckbands in order to estimate population size (via mark-resight) and radiocollared to estimate survival and describe distribution and movement. Some deer were only marked with a neckband, some deer were only radiocollared, and some deer were had both. We color-coded neckbands to easily discern between deer originally captured inside the eastern ROMO boundary (blue) or in Estes Park (yellow); deer captured on the west side of ROMO were marked with white. Sample sizes (number of collars) of each type of collar are presented in the results. For survival and movement analyses, we used expandable radiocollars (Telonics Inc., Mesa, Arizona, USA; Smith et al. 1998) to allow for neck growth in fawns and neck swelling in male deer during the breeding season. For mark-resight, 2 types of identification were employed. If a deer was radiocollared, then a sleeve with a large, unique label was fixed to the radiocollar. If the deer was only to be used in mark-resight analysis (more animals were needed for population estimation than for survival analysis – see below), then an expandable neckband made from hypalon and elastic was put on the captured deer. Deer were captured primarily on winter ranges, but we also captured and radiocollared deer on summer ranges to get a representative sample of deer distribution and movements (Fig. 1). We captured and marked deer just prior to the winter mark-resight count for the first year (winter 2001–2002) of the study. For the following 2 winter mark-resight counts, we captured and marked new deer just prior to winter counts, and then estimated the number of mark-resight collars remaining from previous years based on annual survival rates.

Population Size

We conducted mark-resight counts during mid-December or mid-January throughout mule deer winter range in the Estes Valley. Routes were chosen to cover all known mule deer winter range in the valley, and to maximize the number of deer seen based on historical park records. To estimate population size, we used Bowden's estimator (Bowden and Kufeld 1995, White 1996) because resighting occasions do not need to be composed of independent sighting trials (Bowden and Kufeld 1995). This allowed us to use resighting data collected by foot (in ROMO) and vehicle (in Estes Park). Additionally, we sampled adaptively using Bowden's estimator; that is, we continued resighting until we achieved the pre-determined accuracy. From sample size simulations, we estimated that ≥ 100 marked deer would be needed to achieve a CV of $\leq 10\%$ in ≤ 10 resighting occasions. Resighting efforts were halted each year when we achieved the desired CV. We also collected information on herd composition during the mark-resight counts; this information was used to estimate age and sex ratios (Bowden et al. 1984).

Survival/Mortality Rates

Radiocollared deer were located using aerial telemetry every 6 weeks to 3 months from March 2001–June 2003. Deer were located between 0700–1200 hr using a Cessna 185 fixed-wing aircraft with a 2-element Yagi antenna mounted to each strut of the airplane; all flights were funded and conducted by the CDOW. Because all radiocollars had a mortality switch, the status of each deer, alive or dead, was recorded during each flight.

We used the staggered-entry Kaplan-Meier estimator (Kaplan and Meier 1958, Pollock et al. 1989) to estimate annual and overwinter survival rates. The Kaplan-Meier estimator allowed deer to be entered continuously into the radiocollared sample, and also to be censored when a radiocollar was removed or otherwise failed.

Mule Deer Movements

For all movement analyses, “winter” was defined as 01 December–28 February and “summer” was defined as 15 June–30 September. We used these definitions because 93% of radiocollared deer

were on their winter range by 01 December and 92% were on summer range by 15 June; they then remained on respective seasonal ranges during these timeframes (Conner and Miller 2004).

We radiocollared mule deer from wintering areas and herds throughout the Estes Valley. Our goal was to capture a representative sample of deer throughout the entire park; to accomplish this, we also captured deer on the western side of the continental divide during the summer of 2002 (Fig. 1). For each deer relocation, universal transverse mercator (UTM) coordinates were recorded with a global positioning system (GPS). We then used all summer or winter locations for all deer to define seasonal ranges. Winter and summer ranges were delineated using a kernel home-range estimator using a least-squares cross validation procedure to estimate the smoothing parameter (Worton 1989). Following previous work on delineating seasonal range (Bethke et al. 1996, Taylor et al. 2001, Mauritzen et al. 2002), we subjectively chose 80% use to represent an area commonly used by the Estes Valley mule deer population; 80% was within the 70–90% used to describe seasonal range for these studies. Moreover, the 80% use contour eliminated outlying locations from deer making occasional forays outside of their seasonal range as well as locations of a few deer that moved to summer or winter range later than most ($\leq 8\%$) of their population unit. Seasonal range estimation and delineation were performed in ArcView GIS 3.2 (ESRI, Redlands, California, USA) with the Animal Movements extension (Hooge and Eichenlaub 2000).

Dispersal and migration movements

We used observed winter movement distances and historical data for mule deer in the study area (Siglin 1965, Carpenter et al. 1979, Medin and Anderson 1979, Kufeld et al. 1989, Kufeld and Bowden 1995, Conner and Miller 2004) to develop a criterion to define dispersal, and to distinguish migratory from sedentary movement patterns. From our data, 96% of movements made by radiocollared deer were ≤ 6 km during core winter months when there was no migration. Similarly, an earlier local deer movement study (Siglin 1965) found that migration distances varied between 5–37 km for deer in the Poudre River section of the study area. Thus, we used a simple rule of 6 km as a lower limit for dispersal

or migration movements; that is, a deer was considered to have dispersed if any winter location was ≥ 6 km from any winter location on a previous year and to have migrated if any summer location was ≥ 6 km from any winter location. Only deer with ≥ 1 year or ≥ 8 months of location data were used in analyses of dispersal and migration movements, respectively.

CWD Prevalence on Winter Range

Local estimates of CWD prevalence were primarily based on data collected by CDOW in conjunction with annual hunting seasons during October–November, and on data from live animal sampling supporting ongoing CDOW field studies (Wolfe et al. 2002, 2004). This most likely represented a combined sampling of sedentary and migratory deer in Estes Valley. We assumed that CWD exposure and transmission were more likely to occur on winter range when deer concentrate at relatively high densities compared to other seasons (Mackie 1994). Because surveillance data came primarily from winter range of Estes Valley deer, we regarded the prevalence estimate from the wintering area as best representing the true rate of exposure and infection, and thus used prevalence on winter range as an index of the local infection rate. Prevalence on winter ranges was calculated as the number of CWD-positive deer divided by the total number of deer sampled within the 80% use contour.

Population Model/Dynamics

To explore how best to collect data for monitoring the mule deer in Estes Valley, we constructed a population model parameterized with field data collected 2001–2003. We modeled the population in annual time steps referenced to the time of annual mark-resight and herd composition surveys in December, following harvest. Our model only includes 2 age classes: fawns and adults. We chose to not distinguish yearling from older animals because data were not collected to support this additional classification. Adult survival rates were used for deer in all age categories because of limited data collected on fawn (6 month to 1 year) survival. Thus, we define 3 categories in the population: fawns (or juveniles, J), females (or does, D), and males (or bucks, B). Based on field data, we assessed that males and females had the same survival rates so that $S_D = S_B = S_A$, and, due to lack of data, that $S_J = S_A$. The

gender of fawns did not become explicit in the model until December at which point we assumed a 50:50 sex ratio; this is denoted as g in the model. Fecundity was represented by December recruitment, denoted as R in the model, and defined as the number of fawns per doe. Deer were considered to survive and then be harvested. Harvest was included in the model explicitly for males, $H_B(t)$ and females, $H_D(t)$. We considered harvest mortality to be additive and independent of natural mortality; thus harvest estimates were simply subtracted from the equations used to calculate $N_B(t+1)$ and $N_D(t+1)$. The number of mule deer harvest from the Estes Valley area was estimated by multiplying CDOW harvest estimates for 2001, 2002, and 2003 for Data Analysis Unit (DAU) 10 (CDOW unpublished data), which encompasses the Estes Valley, by the estimated proportion of deer harvested from the Estes Valley population. Using samples with UTM coordinates, we estimated the proportion of deer harvested from the Estes Valley as the number of harvest samples within 10 km of Estes Valley winter range boundary divided by the total number of harvest samples in DAU 10. The model has the basic form:

$$N_T(t) = N_D(t) + N_B(t) + N_J(t),$$

and the equations to project the population from year t forward to year $t+1$ are:

$$N_B(t+1) = N_B(t) \times s_A + N_J(t) \times (1-g) \times s_A - H_B(t),$$

$$N_D(t+1) = N_D(t) \times s_A + N_J(t) \times g \times s_A - H_D(t),$$

$$N_J(t+1) = N_D(t+1) \times R, \text{ and}$$

$$N_T(t+1) = N_D(t+1) + N_B(t+1) + N_J(t+1).$$

To fully explore population dynamics, we included sampling variation of field estimates of initial population size, survival, and recruitment rates, and a reasonable range of mule deer harvest into the model. To estimate the expected population size for model verification and population projection under

several reasonable management scenarios, we ran 1000 parametric bootstrap simulations that included these sources of sampling variation. Where data were missing, we used the mean for years when data were collected.

RESULTS

Population Size

There were between 123–243 deer with uniquely marked collars used in the mark-resight analysis (Table 1). Mark-resight counts occurred during mid-December or mid-January throughout mule deer winter range in the Estes Valley. Population size decreased from 833 to 561 during the study (Fig. 2); population size for winter 2003–04 was 33% lower than the population size for winter 2001–02 ($P = 0.002$). We collected information of age and sex composition during our mark-resight counts and estimated age:sex ratios (Table 2). Age and sex ratios for Estes Valley mule deer were similar to those of foothills deer in other parts of Larimer County (Table 3). Using estimated population size and estimated age:sex ratios, we estimated the number of adult male, adult female, and fawns in Estes Valley during the study period (Table 4).

Survival/Mortality Rates

Survival was relatively constant during the 2 years of the study. Annual mule deer survival was 0.77 (Table 5) for both years of the study and overwinter survival was approximately 0.90 (Table 6). In general, annual female survival was slightly lower than for males (Table 5). However, the difference in annual survival between the sexes was too small (<10%) to determine whether it was due to sampling variation or a biological reality.

Mule Deer Movements

A total of 329 locations were collected from the 63 radiocollared deer during the study period. By design, winter range was in the Estes Valley (Fig. 3). Mule deer summer range encompassed the Estes Valley and areas to the west (Fig. 4). There were 44 radiocollared deer having ≥ 8 months of location data; only these deer were used to evaluate dispersal statistics. No deer dispersed from the Estes Valley. However, 1 yearling buck moved the center of his winter range approximately 4 km to the

southeast from downtown Estes Park after the winter of 2001–2002. There were 37 radiocollared deer having ≥ 1 year of location data; only these deer were used to evaluate migration statistics. There was a mix of migratory and sedentary deer in the Estes Valley population. Approximately 49% (95%CI = 33–65%) of Estes Valley mule deer migrated from winter to summer range. The mean migration distance was 20.2 km (95%CI = 16.3–24.1 km). Most migration was to the west or northwest (Fig. 4), and 15–20% of the radiocollared deer moved close to or over Continental Divide during the summers of 2002 and 2003.

Additionally, from a concurrent study of deer movement in the CWD endemic area (Conner and Miller 2004), we found no interchange between deer from Estes Valley and deer wintering in other areas during the winter (Fig. 5a); however, there was some interchange during the summer (Fig. 5b). The highest interchange with deer wintering outside Estes Valley came from the Masonville area. Approximately 5–10% of 24 deer radiocollared on winter range in Masonville summered in the Estes Valley. There was also limited summer interchange with deer wintering along the Poudre River and in the Lyons area (Fig. 5b). That is, 1 EV and summered in Long Draw in the summer range of Poudre River deer, and 1 Lyons deer summered in the Estes Valley. There was no exchange between Estes Valley deer and deer from other wintering areas. Analysis from Conner and Miller (2004) revealed that the flow of CWD was potentially from mule deer in Masonville or Lyons to mule deer in Estes Valley. Because of western summer migration patterns, Estes Valley mule deer could spread CWD to mule deer populations in Middle Park.

CWD Prevalence on Winter Range

We estimated CWD prevalence from 261 mule deer sampled within Estes Valley mule deer winter range (Fig. 3) between 1997–2002. CWD prevalence in the Estes Valley was 5.4% (95%CI = 2.7–8.1%).

Population Model/Dynamics

Sex and age ratios of mule deer in Estes Valley were similar to those estimated for mule deer in the foothill area of Larimer County (Tables 2 and 3). Adult survival rates of Estes Valley mule deer (mean = 0.77) were slightly lower than for mule deer in the foothill area of Larimer County (mean value for does 1998–2000 = 0.82), but were not statistically different. Based on the vital rates and harvest numbers estimated from field data, the Estes Valley population should be slightly decreasing (~11% decrease) as predicted by the deterministic population model (Table 7), rather than dramatically decreasing (33% decrease; Table 7) as portrayed by the mark-resight estimates (Fig. 2).

In general, adult female survival drives population growth rates for mule deer (Carpenter 1998, White and Bartmann 1998, Unsworth et al. 1999); survival rate for Estes Valley does (0.75, SE = 0.07) was about 9% lower than for Larimer County does (0.82, SE = 0.06; CDOW unpublished data), and about 12% lower than for does in the intermountain west (mean = 0.85, SE = 0.01; Unsworth et al. 1999). Thus, doe survival rates were unlikely to be responsible for the high model predicted population size (relative to observed population size). Other possibilities for the discrepancy between model predictions and field estimates include sampling variation, omission of some dispersal or harvest mortality, or a too-high population estimate in 2001. Because the estimated dispersal rate was 0 for Estes Valley mule deer, and more generally $\leq 2\%$ for mule deer populations in Larimer County (Conner and Miller 2004), we did not pursue the addition of dispersal to our model. Thus, we explored the remaining 3 possibilities by using the sampling variance of our estimates to add stochasticity to the deterministic model, and then using this stochastic model to explore the effects of different realistic levels of harvest mortality (0–60 bucks and 0–30 does; CDOW unpublished data) and initial population size (from mean = 833 to lower 95%CI = 659) on model predictions (highlighted cells in Table 8). We also chose harvest levels that minimized the difference between model predicted population size in 2002 and 2003 and corresponding mark-resight estimates (italicized cells in Table 8). We present population size for 2003 for model verification, and for 2010 to evaluate model behavior and predicted population dynamics (Table 8).

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

Due to methodology problems during the first year of the mark-resight study, variance of the first year mark-resight population estimate is twice that of the subsequent 2 years. Thus, we thought the high first year estimate might reflect sampling variance or reality, and to check we varied the initial population size from the mean mark-resight estimate for 2001 to the value of its lower 95% interval. When the initial population size was reduced from 833 (mean) to 659 (lower 95%CI), the deterministic model predicted population sizes conformed extremely well to mark-resight estimates (Table 9), but this close agreement may be coincidental. To robustly evaluate model predictions with the lower initial population size we incorporated variance of all estimates into the model. When variance was incorporated we found the model was not sensitive to initial population size; that is, similar population trends resulted at relatively similar harvest levels for the 2 initial population sizes. However, varying the initial population size while concurrently varying harvest levels revealed an interesting result: that is, when harvest numbers were set such that predicted population size in 2002 and 2003 reasonably matched mark-resight estimates, then the population declined to low levels by 2010 (italic rows, Table 8). We considered the mule deer population “crashed” when the mean (of 1000 simulations) population size was ≤ 200 in the year 2010; using this criterion the population crashed $\geq 57\%$ of the time for either initial population size. Moreover, there was no way to balance harvest to match the population decline seen 2001–2003 and then have a sustainable mule deer population.

The decrease in population size predicted by the deterministic model corresponded with lower adult female survival rates. That is, adult female survival for Estes Valley was about 10% lower than expected for female mule deer in the intermountain west (Unsworth et al. 1999), and the predicted population size decreased 11% from 2001 to 2003 (Table 7). Thus, it seems likely that relatively low adult female survival in Estes Valley mule deer may be at least partially responsible for the population decline. Field data suggest that vehicle collisions and barbed wire fencing appeared to contribute to the mortality rate above what might be expected in a non-suburban mule deer population.

Because adult female survival was relatively low and mule deer population dynamics is largely driven by adult female survival (White and Bartmann 1998, Unsworth et al. 1999), doe harvest has considerable influence on Estes Valley population dynamics, as verified by model sensitivity to this parameter (Table 8). If ROMO decides a management goal is to maintain Estes Valley mule deer population size close to the current level, then doe harvest should be minimized. However, the ROMO goal of maintaining the mule deer at current densities may conflict with CDOW goals to manage CWD. With these potentially conflicting goals, we recommend that at a minimum, doe harvest is monitored more closely for the Estes Valley mule deer population.

Mule deer migrate into and out of the Estes Valley during the summer. Because CWD exists at higher prevalences in the Lyons and Masonville areas (10.4% and 18.3% respectively; Conner and Miller 2004) than in the Estes Valley (5.4%), it is unlikely that CWD will flow from the Estes Valley to the foothills. However, given the western migration of some Estes Valley deer over the Continental Divide, it is possible that CWD could flow from the Estes Valley into the Middle Park area, where prevalence is relatively low (0.8% and 2.0% for mule deer and elk respectively; CDOW unpublished data). CWD monitoring should be continued on the western slope of ROMO to monitor potential spread of CWD into Middle Park.

For major mule deer populations in Colorado, CDOW collects age and sex ratios and estimates of antlered and antlerless deer harvest annually to build models and predict population size. However, mule deer dynamics and population estimates are most sensitive to adult female survival rates (White and Bartmann 1998). White and Bartmann (1998) suggest that more effective monitoring is accomplished by shifting resources from estimating recruitment (from age and sex ratios) to estimating overwinter survival in mule deer. Radio telemetry studies are typically employed for survival estimation, but the costs and logistics of data collection make it impractical for many situations. Because of the relative ease of resighting Estes Valley mule deer, we propose a different approach that would allow survival estimation as well as estimation of recruitment, age and sex ratios and population size. This is a new approach that could be implemented as part of ongoing research at ROMO with relative ease.

We recommend the development of a mark-recapture data collection methodology based on routes now used to estimate population size. This would involve visibly marking (via eartags or neckbands) all deer captured as part of CWD programs carried out by ROMO and CDOW. Date and location of capture would be recorded, as well as any mortality or loss/removal of collar for marked animals. Then, 4–6 days of “recapturing”, which is resighting in this design, would take place in December and June each year. This design could be analyzed as a robust mark-recapture design (Kendall et al. 1995, Kendall et al. 1997), which would produce estimates of population size and survival rate. Note that age and sex ratios (and hence recruitment) are easily collected as part of the 4–6 day recapture data. The variance of population size and survival rates may be slightly greater than those estimated from separate mark-resight and telemetry studies, but benefits of lowered costs and ease of implementation may outweigh the downside of increased variance. Additionally, the technique described by White and Lubow (2002) on fitting population models to multiple sources of data could be readily employed to increase flexibility of data collection schemes. A population model based on a robust mark-recapture design, but constructed to accommodate other sources of data (White and Lubow 2002) could provide improved estimates of population size, especially when some data is not collected on a particular year.

Based on the field data from 2001–2003, simulations should be preformed to determine likely variance of population size and survival rates, and to refine the sampling design. Results from this design could be compared for performance against the 2001–2003 estimates. This sampling design would allow ROMO biologist and managers to effectively monitor the mule deer population of Estes Valley and assure proper management of this valuable local wildlife resource.

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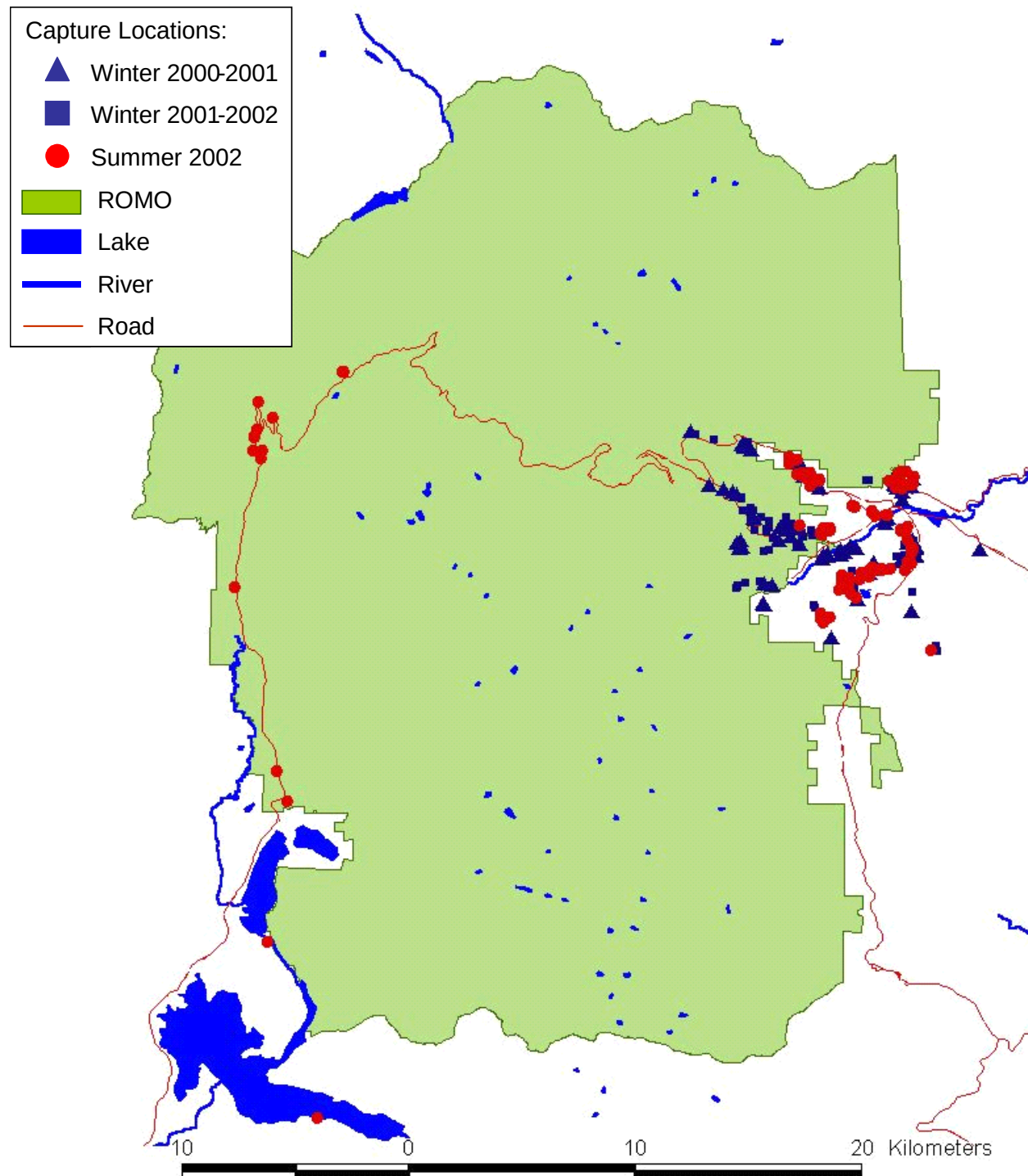


Figure 1. Capture locations of Estes Valley mule deer, 12 March 2001–13 August 2002.

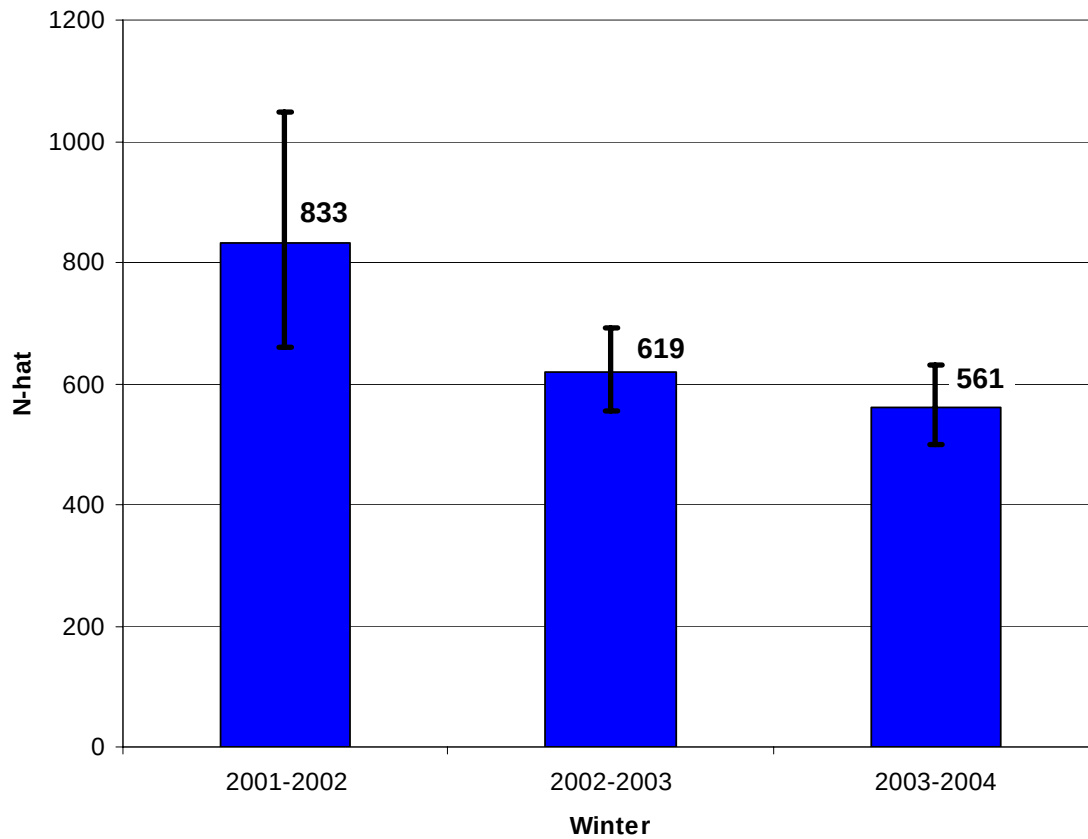


Figure 2. Estimated population size of mule deer wintering in the Estes Valley. Population size estimated using Bowden's estimator for mark-resight data, bars represent the 95% confidence interval.

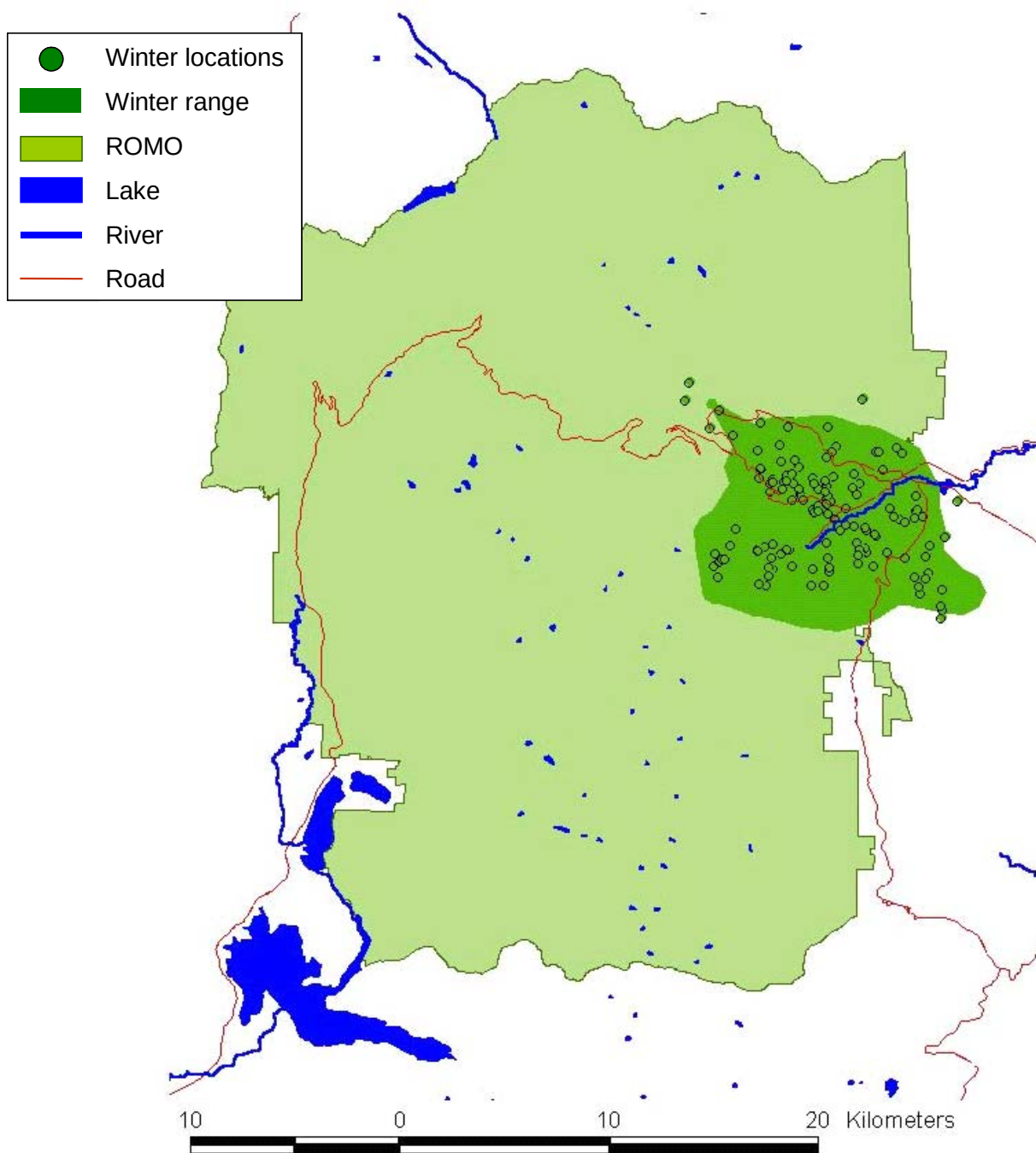


Figure 3. Locations and winter range of radiocollared mule deer in Estes Valley during winter (01 December–28 February) 2002 and 2003.

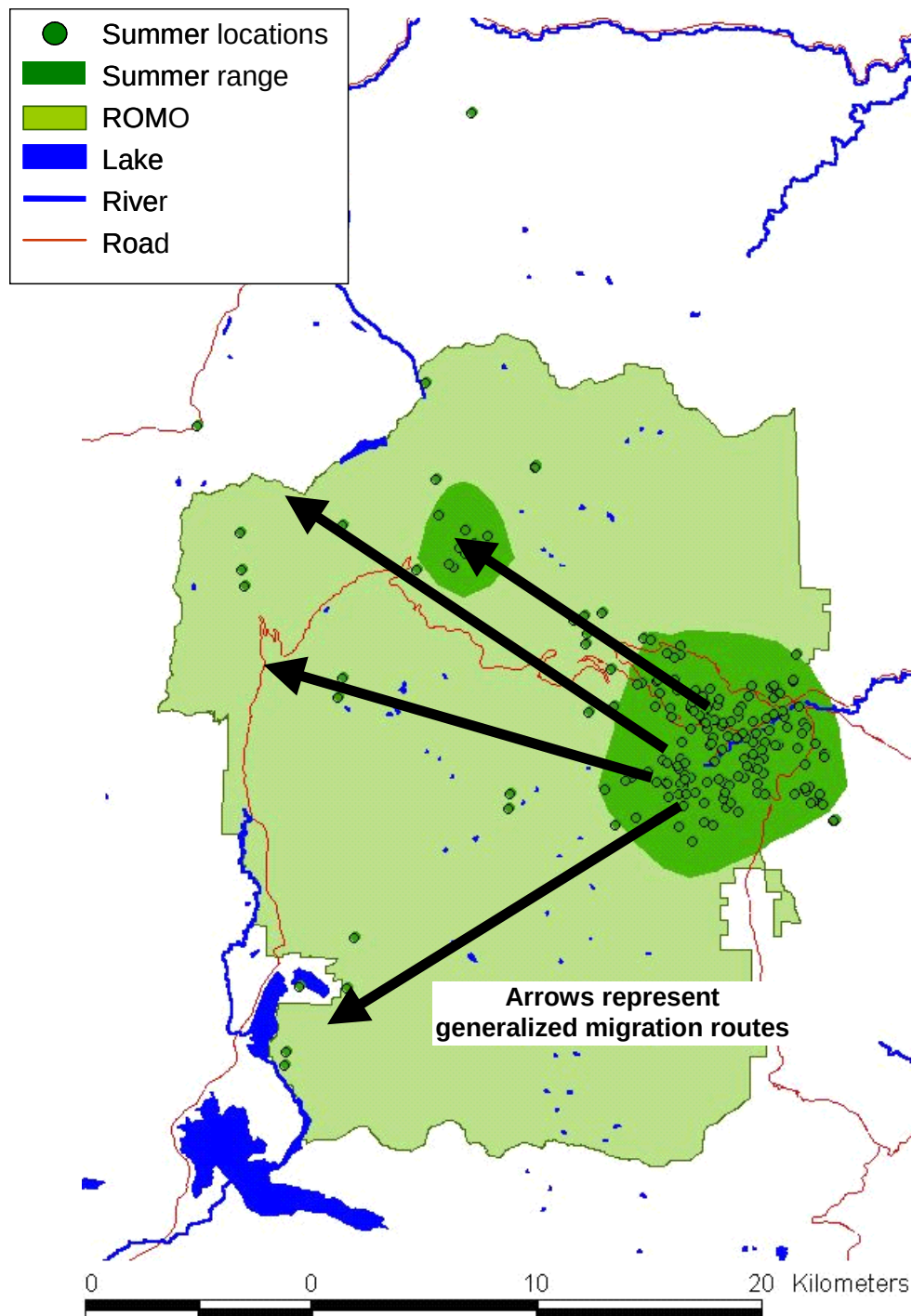


Figure 4. Locations and fixed kernel 80% utilization contours for radiocollared mule deer in Estes Valley during summer (16 June–30 September) 2001–2003.

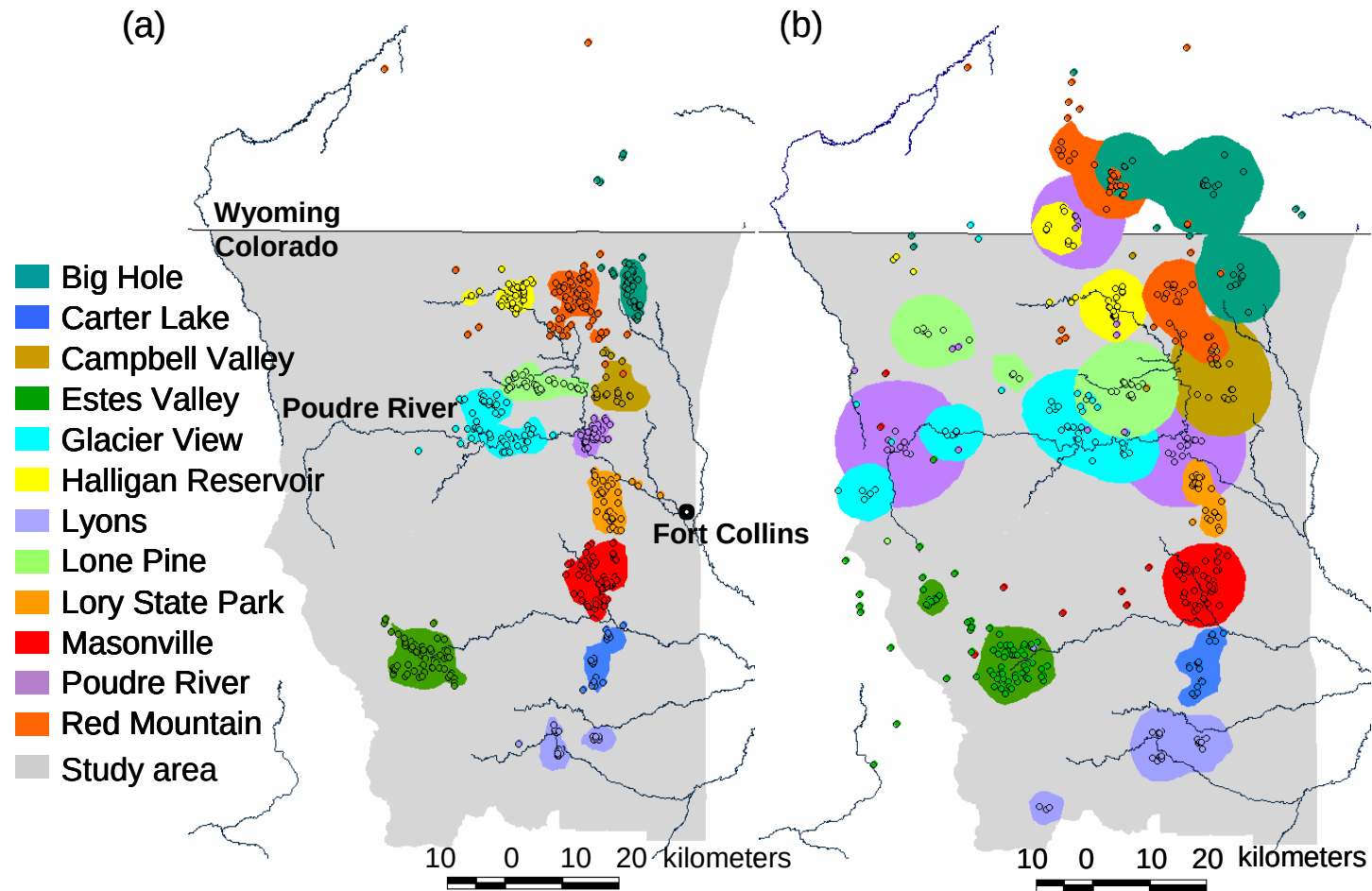


Figure 5. Locations and fixed kernel 80% utilization contours for 11 nearby population units defined by cluster analysis (Conner and Miller 2004) of median winter locations of 352 radiocollared mule deer during (a) winter, 01 December–28 February and (b) summer, 15 June–30 September, in northcentral Colorado, December 1996–January 2003.

All,

This is the long awaited report of the study conducted by CDOW and CSU on mule deer populations on the East Side of the park. The good news is that we were incorrect in our concerns about declines of mule deer when the study began. The bad news is that there are some serious implications from this work. The study shows:

- 1) There appears to have been a marked decline in numbers over the period of study (2001-2004). Although the first year's estimate may have been high, there is still a clear decline from the winter of 2002-2003 to 2003-2004.
- 2) Current harvest levels (including removal of CWD infected deer) are predicted to result in population declines with "no way to balance current harvest rates and stable deer populations." i.e. we are driving the population to a crash by removing CWD infected deer and through other types of harvest. This study says nothing about what leaving the CWD infected deer would do. But since we are removing deer that the disease would remove, we should expect a crash as a result of the disease. Finally, CWD control is not the only harvest-related mortality—there are other types of harvest, including cars and barbed wire, in this deer population.
- 3) Estes Valley deer populations are not thought to present a threat to deer populations to the east of the park, but may present a threat to those west of the Continental Divide by spreading CWD. CWD prevalence is higher in deer in the Estes Valley (5.4%) than in deer (0.8%) or elk (2.0%) in the Middle Park area.
- 4) The study suggests a monitoring plan, that would involve small changes in CDOW's and our current CWD efforts, and that would involve about 4 to 6 days of work in December and a similar amount in June. It would allow the park to have a good handle on what is happening to the deer population, and would tell us if the deer populations are in serious decline as CWD management continues.

Please be aware that the management implication of this work is **not** that we quit managing CWD. I do think, however, that we should discuss the possibilities of monitoring, as recommended, to see if, and how fast, the population declines.

Table 1. Summary statistics used to estimate mule deer population size in Estes Valley via Bowden's estimator (Bowden and Kufeld 1995, White 1996).

Winter	Month of Count	Number of days count conducted	Number marked with MR collars	Number unmarked counted	Approx CV
2001–2002	Jan (2002)	6	123	699	11.9%
2002–2003	Jan (2003)	4	243	437	5.6%
2003–2004	Dec (2003)	6	125	1111	6.1%

Table 2. Estimated age and sex ratios (Bowden et al. 1984) of mule deer in Estes Valley.

Winter	Number of groups ^a	Proportion buck	SE	Proportion doe	SE	Proportion fawn	SE	Sample Size ^b
2001–2002	41	0.202	0.020	0.467	0.016	0.330	0.018	815
2002–2003								
2003–2004	40	0.183	0.011	0.545	0.013	0.272	0.013	1437

^a A group was the route total for a given day; e.g., day 1 route 1 was group 1, day 1 route 2 was group 2, etc.

^b Sample size was the total number of marked and unmarked deer identified to age and sex class during mark-resight counts.

Table 3. Estimated age and sex ratios of mule deer in foothills of Larimer County.

	1995–1998	2000–2001
	mean	mean
Proportion fawn	0.296	0.268
Proportion does	0.587	0.546
Proportion bucks	0.117	0.186
Recruitment rate	0.546	0.491

Table 4. Estimated population size by age and sex classification of mule deer in Estes Valley based on total estimated population size and estimated age and sex ratios.

Population	2001–2002	2002–2003 ^a	2003–2004
Total	833	619	561
No males	169	125	103
No females	389	289	306
No fawns	275	204	153
No adults	558	415	408

^a Sex and age proportions from 2001–2002 used because no age:sex data collected 2002–2003.

Table 5. Kaplan-Meier estimated annual survival of adult mule deer in Estes Valley.

Year	Sex	Number	S	95% Confidence Interval	
		radio collars ^a		Lower	Upper
2001–02	Both	28–39	0.77	0.57	0.96
	Femal		0.75	0.48	1.00
	e Male		0.82	0.59	1.00
2002–03	Both	32–50	0.77	0.66	0.89
	Femal		0.75	0.61	0.89
	e Male		0.84	0.63	1.00

^a The number fluctuated due to staggered entry of collars throughout the year and loss of collars due to mortality; thus we report the range of collars (sample size) used in Kaplan-Meier survival estimates.

Table 6. Kaplan-Meier estimated overwinter survival of adult mule deer in Estes Valley.

Year	Sex	Number	S	95% Confidence Interval	
		radio collars ^a		Lower	Upper
2001–02	Both	28–39	0.91	0.81	1.00
	Femal		0.96	0.88	1.00
	e Male		0.81	0.59	1.00
2002–03	Both	32–50	0.90	0.81	0.99
	Femal		0.90	0.79	1.00
	e Male		0.90	0.74	1.00

^a The number fluctuated due to staggered entry of collars throughout the year and loss of collars due to mortality; thus we report the range of collars (sample size) used in Kaplan-Meier survival estimates.

Table 7. Predicted mule deer population size in Estes Valley based on a deterministic population model, input parameter estimates from field data collected 2001–2003.

Year	Number bucks	Number does	No. fawns recruited	Total bucks. harvested ^a	Total does harvested ^a	Model predicted pop. size	Field estimated pop. size ^b
2001	168	389	275	45	14	833	833
2002	235	404	244	44	20	806	619
2003	276	407	203	45	17	747	561

^a Harvest estimates subtracted before calculating total population size; that is, harvest was subtracted from estimated number of bucks and does.

^b Field estimated population size based on mark-resight counts and Bowden's estimator.

Table 8. Predicted mule deer population size ($\hat{N}$) based on a stochastic population model and various initial population sizes and harvest levels. Highlighted cells represent realistic levels of harvest and italicized cells represent levels of harvest that minimized differences between population model estimates and mark-resight estimates for 2001–2003.

Initial pop. size	No. bucks harvested	No. does harvested	$\hat{N}_{2003}$ (SE)	$\hat{N}_{2010}$ (SE)	% sims $\hat{N}_{2010} < 200$
833	0	0	934 (143)	1060 (261)	0
833	50	0	841 (139)	879 (284)	0
833	50	25	769 (120)	391 (224)	2.2
833	<i>100</i>	<i>50</i>	<i>587 (147)</i>	<i>11 (26)</i>	<i>91.4</i>
833	300	28	313 (143)	0	98.6
659	0	0	734 (142)	826 (215)	0
659	50	0	658 (138)	639 (216)	0
659	50	25	566 (134)	184 (215)	21.9
659	50	30	541 (112)	105 (141)	41.9
659	<i>60</i>	<i>30</i>	<i>523 (139)</i>	<i>72 (123)</i>	<i>52.4</i>

Table 9. Predicted mule deer population size in Estes Valley based on a deterministic population model, input parameter estimates from field data collected 2001–2003, and an initial population size of the lower 95% CI from the first years estimate.

Year	Number bucks	Number does	No. fawns recruited	Total bucks. harvested ^a	Total does harvested ^a	Model predicted pop. size	Field estimated pop. size ^b
2001	133	309	217	45	14	659	659
2002	141	300	181	44	20	622	619
2003	135	285	142	45	17	562	561

^a Harvest estimates subtracted before calculating total population size; that is, harvest was subtracted from estimated number of bucks and does.

^b Field estimated population size based on mark-resight counts and Bowden's estimator.